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AUTOMATON FOR ACORNS SCARIFICATION - KINEMATIC AND STRENGTH CALCULATIONS OF SELECTED COMPONENTS

Summary

The computer model of the scarification machine was created at the Industrial Institute of Agricultural Engineering in Poznań with the participation of employees from the AGH University of Science and Technology in Krakow and the University of Agriculture in Krakow. The automaton is the result of the project, which aim was to develop, build and test an automatic device used to carry out the scarification of oak seeds for later shortening and balancing of germination period and elimination of sick and spoiled seeds. The paper presents the results of kinematic and strength analyzes of selected elements of the research model of a scarifying machine - the course of the peripheral speed, acceleration, torque and stress generated during the rotation of the arm.

Keywords*: acorns, scarification, kinematic analyze, dynamic analyze, vibrations*

ANALIZA KINEMATYCZNA I WYTRZYMAŁOŚCIOWA WYBRANYCH PODZESPOŁÓW AUTOMATU DO SKARYFIKACJI ŻOŁĘDZI

Streszczenie

Komputerowy model automatu do skaryfikacji powstał w Przemysłowym Instytucie Maszyn Rolniczych w Poznaniu przy współudziale pracowników z Akademii Górniczo-Hutniczej w Krakowie oraz Uniwersytetu Rolniczego w Krakowie. Automat ten jest efektem zrealizowania projektu, którego celem było opracowanie, zbudowanie i przetestowanie automatycznego urządzenia służącego do prowadzenia skaryfikacji nasion dębu w celu późniejszego skrócenia i wyrównania okresu kiełkowania oraz eliminacji chorych i zepsutych nasion. W pracy przedstawiono wyniki przeprowadzonych analiz kinematycznych i wytrzymałościowych wybranych elementów modelu badawczego automatu skaryfikującego – przebieg wartości prędkości obwodowej, przyspieszenia, momentu obrotowego oraz naprężenia generowanych podczas obrotu ramienia.

Słowa kluczowe*: żołędzie, skaryfikacja, analiza kinematyczna, analiza dynamiczna, drgania*

1. Introduction

Modern technologies and techniques of nursery production require very high quality seeds, so that each seed can grow with specific morphological parameters.

Increased sowing performance is particularly important in the case of oak, because the species is characterized by very uneven emergence. The first seedlings begin to appear 2-3 weeks after sowing, and the last even after 16-17 weeks. It results in a varied seedling growth and increases competition between them. Seedlings appearing later are under the cover of larger seedlings with well-developed leaves, which effectively limit the access of light and water. Unevenness of emergence, and then growth, affects the sowing performance [1, 2, 3].

The low efficiency of mechanical methods of separation of acorns with the use of classical distribution features, such as density, aerodynamic properties, size and shape, frictional properties and elasticity, prompts the search for unconventional solutions [4, 5]. Acceleration and leveling of emergence enables tedious mechanical scarification of the seeds, until now performed manually, usually with the help of a pruning shears, followed by a visual assessment of the viability of seeds by the worker. A less frequently used method is mechanical cutting off of a piece of seed using a suitably adapted grinder. In this way (mainly hand-made) several tens of millions of seeds are prepared for sowing in Poland in a period of about 3 months (from January to March). Such a tedious, monotonous work requires the employment of about dozen of people in each nursery garden. The ergonomic inconvenience of the work consists in the repetitive several thousand times a day movement of hands and hands in the cycle: picking up seeds (or a few seeds) from the tank by the hand, cutting the seed section with a pruning shears, visually assessing the germination of the seed on the basis of the color of the cotyledon and the degree of filling of the seed cover, transfer of the seed to the appropriate tray. Even the use of modern pruning shears causes the nervous-muscular system of the hands and hands to become repetitive [6, 7, 8, 9].

2. Models description

As a part of the 5th task of the project, virtual 3D solid models of the main teams of the designed machine for abortion scissors were developed. Fig. 1 shows the general view of the site.

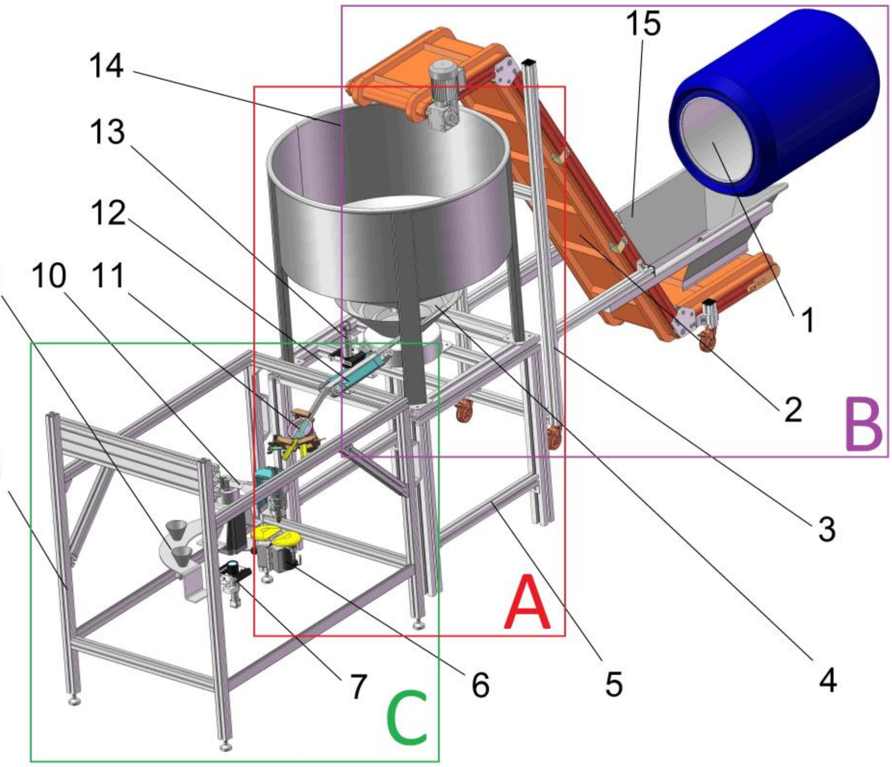

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Fig. 1. The physical model of the automaton for evaluation and scarification of oak seeds; A – vibrating screen section, B – vision and scarifying section, C – conveyor and tank band
Rys. 1. Model fizyczny automatu do oceny i skaryfikacji nasion dębu; A – sekcja podajnika wibracyjnego, B – sekcja wizyjna i skaryfikująca, C – zespół przenośnika i zasobnika

The construction of the stand is supported on three independent frames. Each frame is a separate working unit, so three groups can be distinguished: a band conveyor assembly (A), a vibratory feeder unit (B) and a basic scarification band (C) – Fig. 1. A hopper (15) is attached to the frame of the belt conveyor (3), to which the acorns from the tank in which they were delivered are fed (1). The acorns are then transported by the conveyor (2) to the hopper (14) of the scarification unit. From the basket, the acorns fall into the vibratory feeder (4). The hopper as well as the vibratory feeder are based on their own frame (5). In the next step, the acorns are transported by a belt conveyor (12), over which the camera (13) is fixed to register the direction of the transferred acorn. Then the acorn is transported to the orientator (11), which, depending on the signal from the camera over the conveyor (13), places it in the right direction. The next stage is placing the acorn in the gripper (10), which, by performing a full rotation, allows the tip of the acorn to be cut by the blades of the cutting unit (6), then assessed by the camera unit (7) and placed in a suitable sorting container (9). The complete scarification process, starting with the transfer of the acorn through the conveyor (12) and ending with the sorter (9) takes place with the use of components embedded in the frame (8) of the third unit [10, 11].

3. Simulations

In order to determine the load values of selected working teams of the designed machine for abbreviated acorns, their kinematics and dynamic simulations were carried out using the Siemens NX software version 10.0. Fig. 2 presents a virtual model of a gripper assembly prepared for the needs of a kinematic-dynamic analysis.

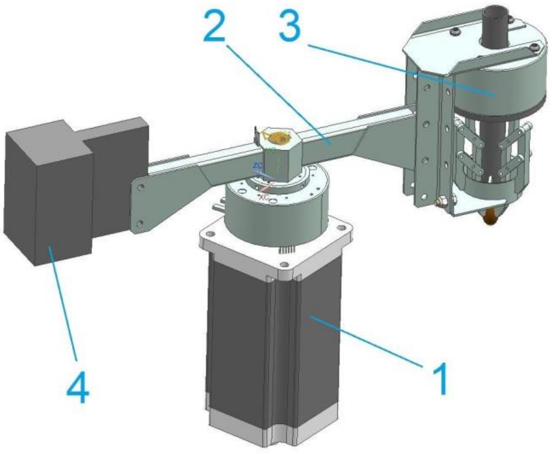

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Fig. 2. Virtual model prepared for the needs of kinematics-dynamic simulation
Rys. 2. Model wirtualny przygotowany na potrzeby symulacji kinematyczno-dynamicznej

The gripper assembly model consists of a motor (1) which rotates the gripper arm (2). The arm is symmetrical - on one side a gripper (3) is attached, and on the other hand a balancing mass (4) to compensate for the radial forces applied to the axis of the stepper motor. The assembly model has been simplified, omitting all screw connections and elements of the electrical system. The necessary masses of individual elements were retained. A gravity vector with a value of $g = 9.81\ m\cdot s^{-2}$ was applied globally to the model. A steel absolute density equal to $q = 7820\ kg\cdot m^{-3}$ was assumed for structural elements. The computer program calculates the mass of the structure based on the volume of the modeled bodies and the density of the material assigned to them. In kinematical-dynamic simulations, loads related to the rotation of the arm with the masses applied on both sides were determined. Motion simulations were carried out in the following variants:

1. Full rotation of the arm lasts 5 seconds,
2. Full rotation of the arm lasts 3 seconds.

The results of the kinematic-dynamic analysis were presented in the form of diagrams in Figs 3-4 for the full arm rotation time of 5 seconds.

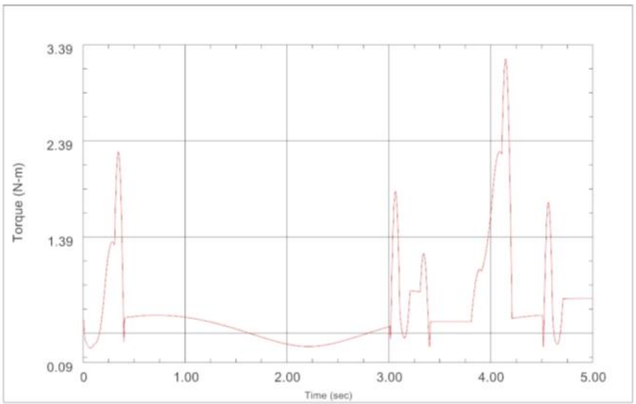

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Fig. 3. The graph of the torque course on the stepper motor shaft, a full rotation lasts 5 seconds, horizontal axis presents time, vertical axis – torque value

Rys. 3. Wykres przebiegu momentu obrotowego na wale silnika krokowego, dla pełnego obrotu trwającego 5 sekund, pozioma oś wskazuje czas, pionowa – wartość momentu

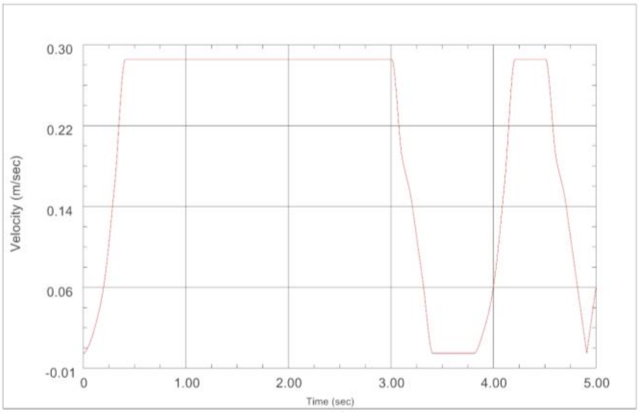

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Fig. 4. Graph of peripheral speed course of a point on a circle staggered by a rotating gripper unit, full rotation lasts 5 seconds, horizontal axis presents time, vertical axis – velocity value

Rys. 4. Wykres przebiegu prędkości obwodowej punktu na okręgu zataczanego przez obracający się zespół chwytaka, dla pełnego obrotu trwającego 5 sekund pozioma oś wskazuje czas, pionowa – wartość prędkości

The maximum peripheral speed of a point on a circle with radius r = 277 mm, plotted by the gripper movement, is v = 0.28 m·s^{-1}, the maximum achieved acceleration during movement is a = 5.8 rad·s^{-2}, while the highest torque is M = 3.2 Nm. In the case of rotation of an arm lasting 3 seconds, the above mentioned characteristics are as follows: v = 0.78 m·s^{-1}, a = 16.5 rad·s^{-2}, M = 8.2 Nm. The results of the simulation were used in the strength analysis of the operating devices of the acorn scarification machine.

4. Strength analyzes

The strength analyzes of the structure of the device's working elements were made using the finite element method, using the determined loads. Achieving the set goals required analytical calculations and strength simulations of the model's structure.

The analyzes were made using a simplified 3D model of the gripper's arm (Fig. 5). The model consists of profiles with rectangular cross-sections welded to a thick-walled pipe with a hexagonal head. The profiles are finished with flat bars made of metal, which are used to attach the gripper and counterbalance. In order to maintain the stiffness of the model, in the place of the openings to which the above-mentioned elements will be fixed in the real model, solid equivalents are placed between flat bars, being simplifications. On the simplified model of the virtual gripper arm, which is one of the elements of a complete oak scarification stand, a FEM (Finite Elements Method) mesh was generated [12, 13].

Source: own study / Źródło: opracowanie własne

Fig. 5. Simplified model of the virtual gripper arm, with the FEM mesh applied, forces applied and restraint

Rys. 5. Uproszczony model wirtualnego ramienia chwytaka z naniesioną siatką MES, przyłożonymi siłami i utwierdzeniem

To the model, in the holes where the red arrows are visible, the force values that were obtained in two variants were applied loads during kinematic simulation. For rotation of 3 seconds, the maximum forces in the arm were 28N, while in the case of a rotation of 5 seconds, these forces were 11 N. The forces were determined on the basis of the obtained torques in kinematical-dynamic simulations.

Figs 6-7 show the reduced stresses occurring in the case of a 28 N force load. The maximum stresses for this load occurred in the joint joining the rectangular profile with the bracket and amounted to 6.1 MPa. The displacements occurring in this load are shown in Fig. 8. The maximum displacement of the arm structure was 0.02 mm at its ends.

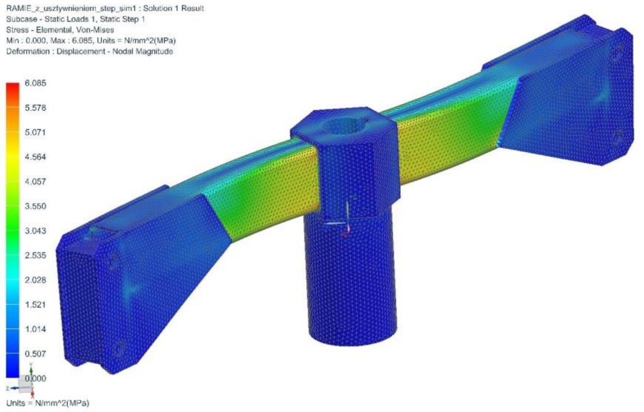

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Fig. 6. Distribution of stresses reduced in the design of the gripper arm model, view of the whole arm
Rys. 6. Rozkład naprężeń zredukowanych w konstrukcji modelu ramienia chwytaka przy sile 28 N, widok całości

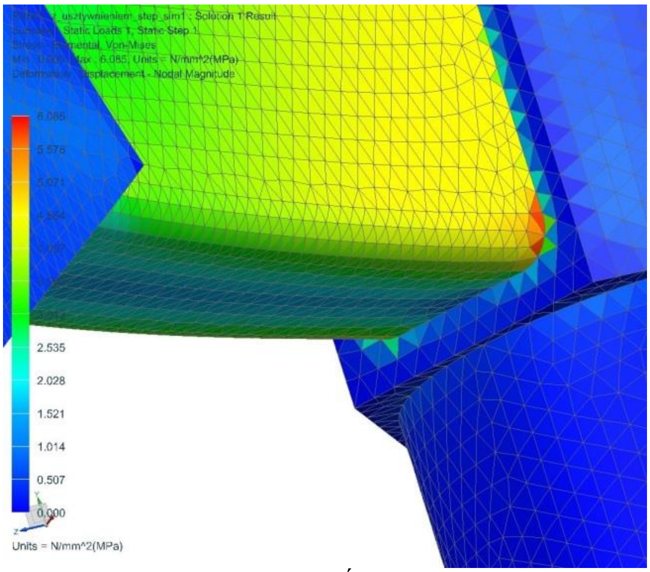

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Fig. 7. Distribution of stresses reduced in the design of the gripper arm model, weld view
Rys. 7. Rozkład naprężeń zredukowanych w konstrukcji modelu ramienia chwytaka przy sile 28 N, widok spoiny

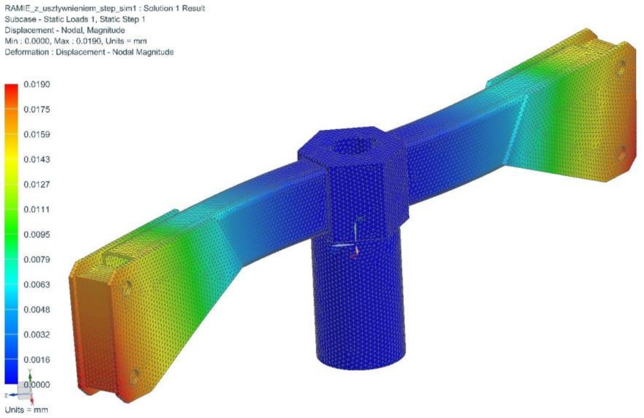

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Fig. 8. Distribution of displacements in the design of the gripper arm model, view of the whole
Rys. 8. Rozkład przemieszczeń w konstrukcji modelu ramienia chwytaka, widok całości

For both load cases, the fatigue strength criterion was determined based on the readout of values for welds from the Goodman Smith chart (Fig. 9).

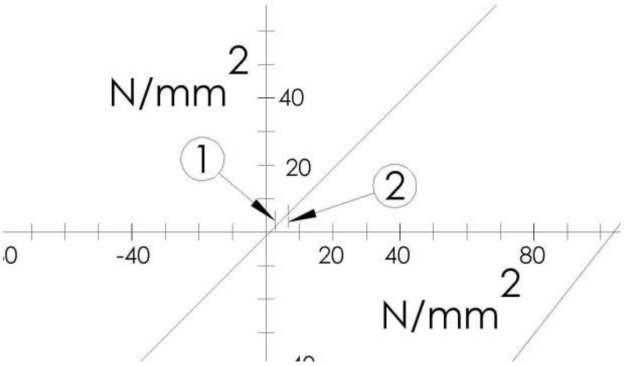

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Fig. 9. Goodman-Smith graph for steel S355J0, enlarging the graphic area showing the results for load cases of the machine structure, 1 – arm rotation within 5 seconds, 2 – arm rotation within 3 seconds
Rys. 9. Wykres Goodmana-Smitha dla stali S355J0, powiększenie graficznego obszaru przedstawiającego wyniki dla przypadków obciążeń konstrukcji maszyny, 1 – obrót ramienia w czasie 5 sekund, 2 – obrót ramienia w czasie 3 sekund

This graph presents a graphical summary of results for stress concentration cases of the structure [14]. In the analyzed structure, the admissible values of stresses were not exceeded (plasticity limit for S355 steel is 355 MPa). Both in the case of loading the arm resulting from the rotation of 5 seconds and from the duration of 3 seconds, the determined maximum values are smaller than the permissible values [14, 15].

5. Summary

At the first stage of the work, kinematical-dynamic studies were carried out on a virtual model. Load values of the gripper's arm, which occur when working with given motion parameters, were obtained. Obtained results of loads were used at the second stage to conduct a multi-variant strength analysis of the gripper's arm. Strength analysis covered two work cases, which determine the rotation of the gripper arm with two different speeds. The obtained results enable to assess that the design of the gripper arm and the vibratory feeder unit and the materials used, meet the requirements set for them. The results of this study were used for create the technical documentation of the prototype, on the basis of which a prototype of a complete machine for the scarification of oak seeds will be created.

The functional model of the machine after construction was tested and the results of the measurements carried out fully confirmed the theoretical predictions. The machine tested in this way has won many awards and medals at exhibitions and fairs.

6. References

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